GRDC Regional Cropping Solutions Network
Final Report

Farmer knowledge on methods to address non-wetting soils

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KW11/12-1of1

Amelioration strategies for non-wetting gravel soils in a high rainfall area

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1. Introduction

Non-wetting is a major problem of the gravelly soils in the high rainfall area of the South Western wheat belt of WA. Non-wetting is caused by a build up of waxes around the soil particles as a product of the breakdown of organic matter. It results in delayed emergence of the crop, staggered germination of weeds, affects the availability of phosphorus as a major but less mobile nutrient and ultimately affects yield.

2. Objectives

To trial a range of non-wetting treatments on non-wetting forest gravel soils in the south west, in a high rainfall area, to determine which, if any, will increase water penetration and what soil characteristics have altered as a result of the treatment. By increasing water infiltration it is expected that there will be an increase in soil cover (plants) and consequently reduced water and wind erosion. Additionally, increasing water penetration higher in the landscape increases plant available moisture, and leads to better plant health and yield. Less staggered germination will increase yield and reduce weed burden which are not only economic drivers but ultimately provide soil cover, build soil carbon and protect against erosion.

3. Methodology

A large scale trial was implemented near Cordering in the West Arthur Shire in 2012, to investigate the effectiveness of a number of management options to alleviate the non-wetting properties or to reduce its impact. They included: the use of wetting agents (Lure and Precision Wetter, as a blanket spray and banded), organic fertilisers (compost and humus pellets), mould boarding (with and without lime), claying (2 rates: 9 and 28 t/ha @ $110/tonne), scarifying and liming at the surface, as well as a Control which consisted of the ‘standard’ practice. The clay consisted of Watheroo Bentonite, because other clay sources were not available at the time. Most of the options were implemented prior to seeding.

The trial layout consisted of 70m x 13.5m plots, with three replicates of each treatment. The plots were sown on the 24th of May with Vlamingh barley and 120kg/ha Gusto TSP and 50kg/ha Urea.

A number of surveys (EM38, radiometrics, gravel and soil) were conducted before the treatments were implemented. Observations included plant counts, soil moisture near the surface, NDVI, runoff, soil microbial biomass, and final yield.

The Balance is a pelletised product, mend to replace some of the nitrogen compound fertilisers at seeding. When that was applied however no compound fertiliser went out at all so the Balance treatment lacked the 120 kg/ha of Gusto which affected the early vigour of the plants dramatically.

The mould board ploughing was done on the 10th of May with a small one-way 3-furrow plough owned by the department. The depth was about 30 cm. A photograph of the plough and the soil profile is presented in Figure 3.1 and 3.2.

Figure 3.1 Three furrow one way mould board plough used at the Cordering trial site.

Figure 3.2 Soil profile in the mould board ploughed plots at the Cordering trial site. Stubby is 10 cm high.

The soil profile consisted of a non-wetting top soil (organic rich), followed by a bleached horizon, and then a more yellow orange gravel with coarse sand. The latter was very moist at the time of ploughing while the top soil was very dry.

4. Results

Rainfall and distribution

The rainfall in 2012 from the nearby weather station is presented in comparison with the rainfall in previous years, see Figure 4.1.

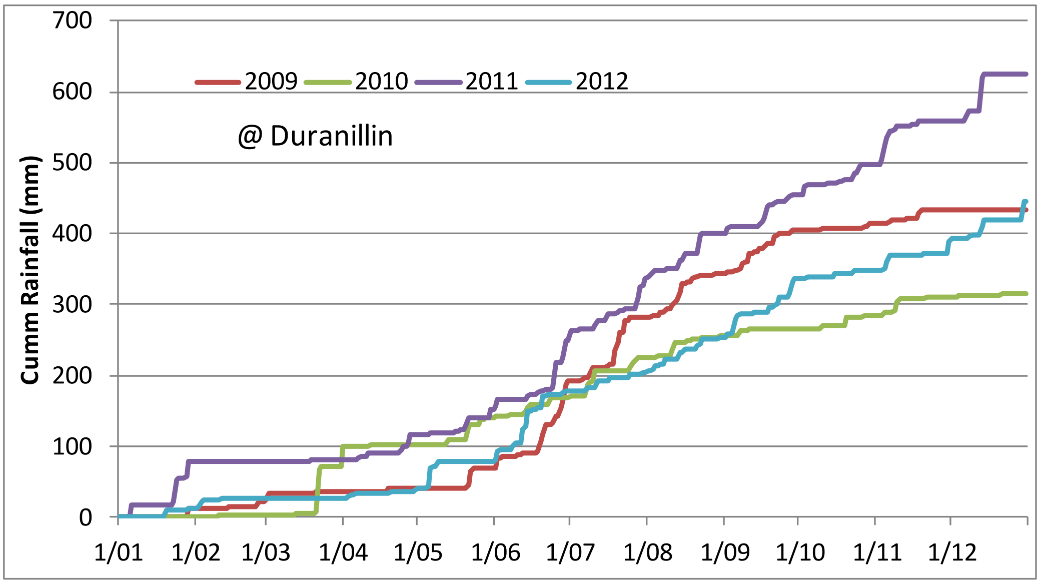
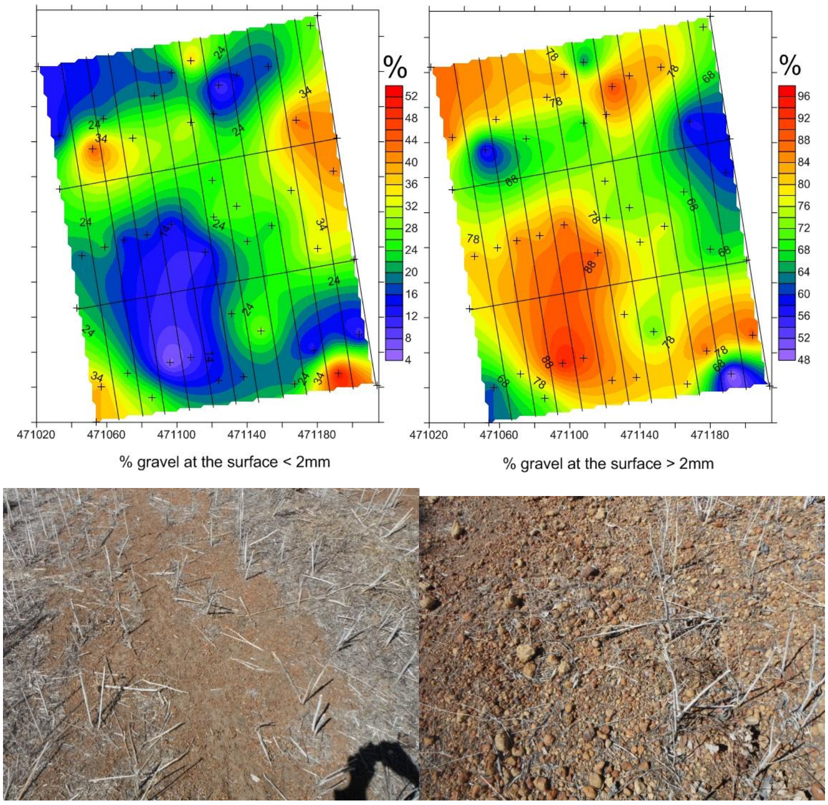


Figure 4.1. Cumulative rainfall from Jan until the end of June at Duranillin in 4 consecutive years

Several large rainfall events marked the start of the season in 2012. This good start to the season had some beneficial implications for the establishment of the crops at the trial site. The total growing season rainfall (April – October) was 405mm.

Gravel distribution.

The site consists of a range of very coarse gravel to small pea-gravel at the surface. Some plots had much more coarse gravel than others. It affected the available moisture and it appeared to affect the non-wetting. More big gravel seems to increase the non-wetting. See Figure 4.2, for the distribution of the gravel across the site and the types of gravel present.



40-50% fine gravel at the surface   70-90% course gravel at surface

Figure 4.2 Distribution of the fine (left) and coarse(right) gravel (top), and the types of gravel at the Cordering site.

Non-wetting properties are measured as MED. An MED of 0 = not non-wetting, 2-3 = moderate and more than 4 is severely non-wetting. The distribution of the MED across the site is presented in Figure 4.3.

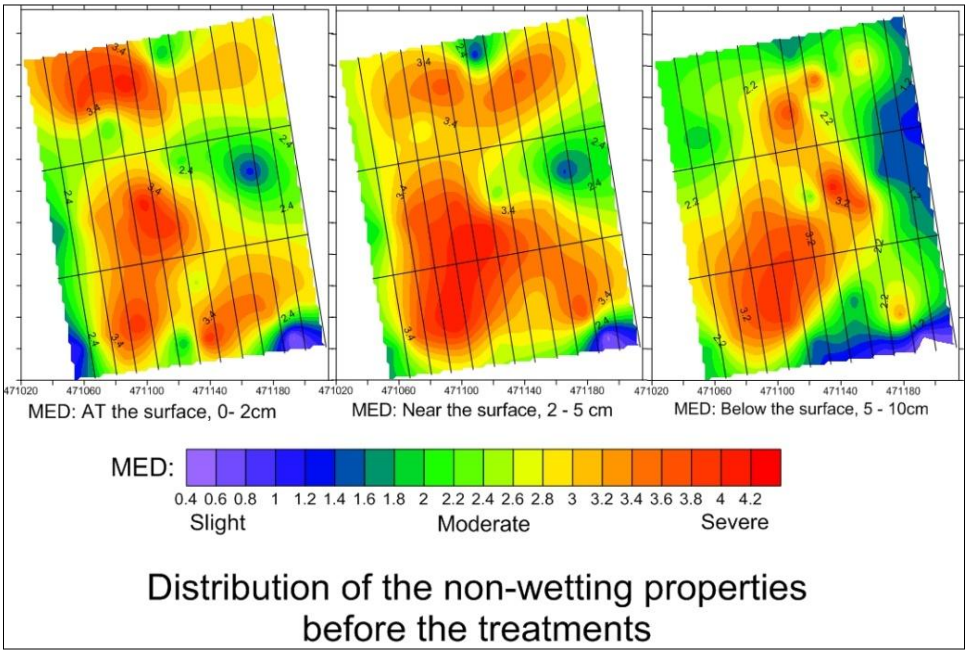


Figure 3. Distributrion of MED at the Cordering site for three different depths.

The non-wetting at the surface varied from moderate to severe (MED:2.8), increased at a depth of 2 - 5 cm (MED: 3.2) and decreased again below that level (MED: 2.1). The soil usually become easily wettable at a depth of 10cm. Most of the seeding occurs at a depth of 2 - 5cm.

Radiometrics

The company Precision Agronomics Australia carried out a radiometric survey to see whether some of the trends in the some of the radiometric parameters could be used to predict trends in the gravel content, and therefore indirectly trends in the non-wetting properties. The radiometric parameters were total count, thorium, uranium, and potassium levels. In addition the shallow and deep soil conductivity was also measured with and EM38. In Figure 4.4 maps of the shallow soil conductivity and the total count are presented. The total count is often used as an indicator for the levels of gravel.

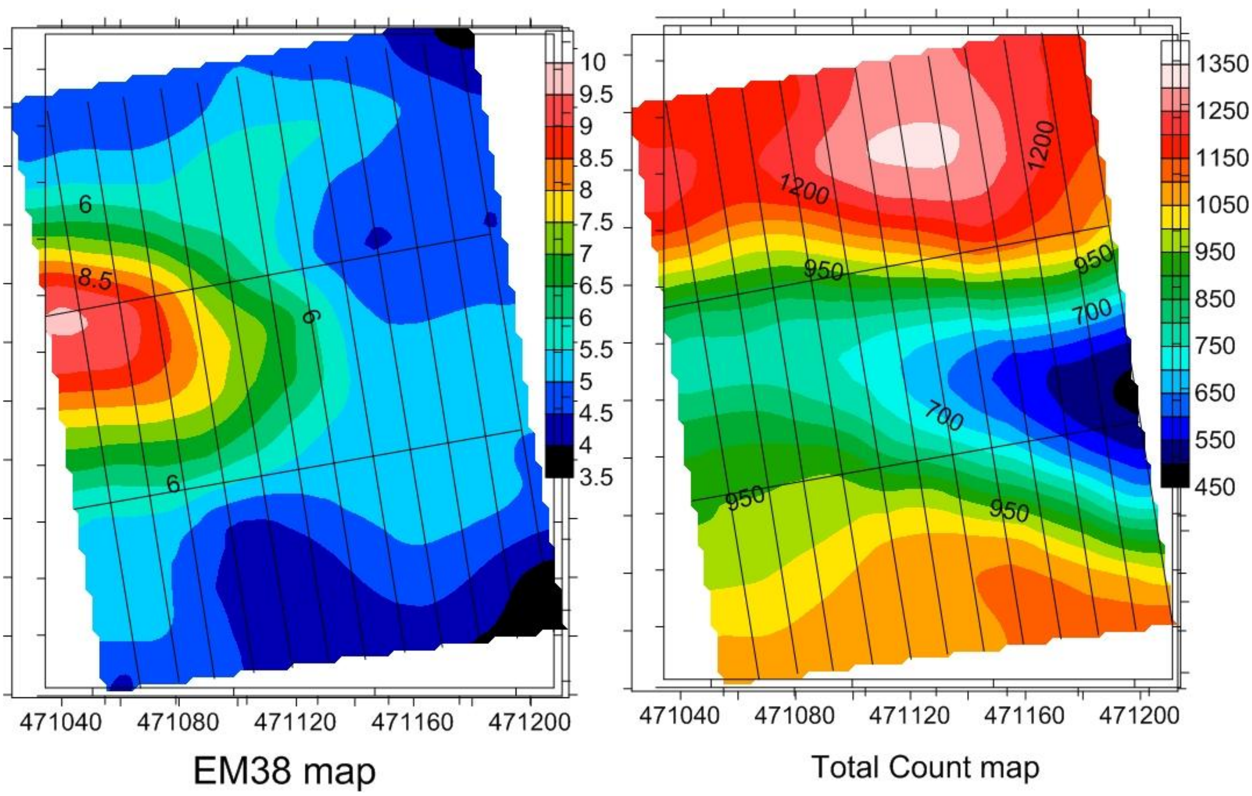


Figure 4.4. Soil conductivity (EM39) and the total count map of the trial site at Harrington.

There was little correlation between the soil conductivity, the total count and the distribution of the gravel at and near the surface. Areas of higher EM38 reading (middle left) and higher Total Count readings (middle right) were areas where either the gravel content or the MED was significantly higher, or lower for that matter.

Soil nutrition:

Range of the soil nutrition results in the top 10cm as measured by CSBP and sampled in March is presented in Table 4.1.

Table 4.1. Average, maximum and minimum soil chemical properties from the Cordering trial site. From 108 samples (0 - 10cm only), Only pH at 10 - 20cm and 20 - 30cm

Property	NH ppm	NO Ppm	P ppm	K ppm	S ppm	OC %	Al	PBI	pH 0-10cm	pH 10-20cm	pH 20-30cm
Mean	5	25	74	73	11	3.6	1.6	138	5.2	5.1	5.2
Max	13	48	108	238	26	5.8	5.4	318	6.1	6.4	6.8
Min	2	9	48	23	3	1.4	0.2	35	4.6	4.0	4.0

The distribution of some of the soil chemical properties is presented in Figure 4.5.

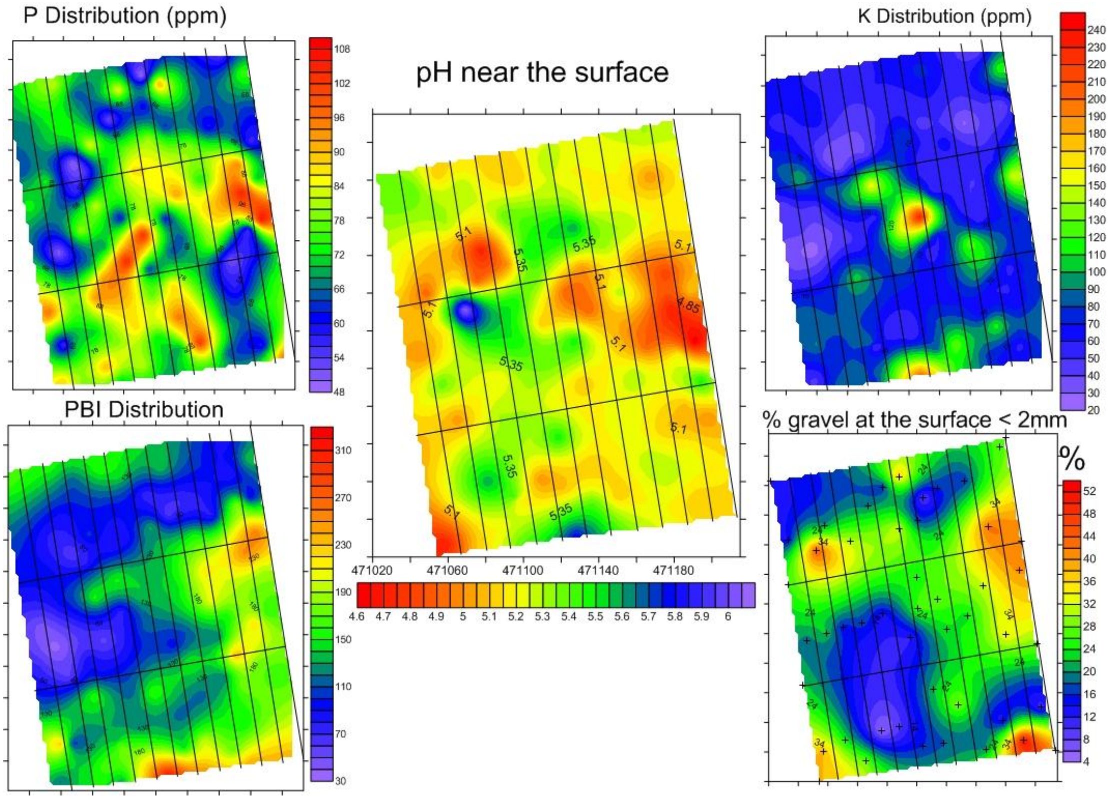


Figure 4.5. Distribution of the levels of P, PBI, pH K and % gravel at the surface at the Cordering site.

There was a correlation between the levels of P, the PBI, the high amount of fine gravel, and the pH looking at the middle of the eastern side. It is probably the better yielding part of the paddock, even though the pH is low but perhaps not yet too low to inhibit crop growth.

Soil moisture and germination

Soil moisture was measured in the plant row and between the rows, and the number of plants per meter were counted 3 weeks after seeding. The results are presented in Table 4.2.

Table 4.2. Soil moisture in the plant rows and between the plant rows and the plants/m for each treatment

Treatment	Soil moisture (%) In the row	Soil moisture(%) Between the rows	Plants/m
Scarifying only	9.8	8.5	18.5
Mould board Ploughing	12.3	13.1	13.9
Lime & Mould board Ploughing	13.1	12.1	10.8
Lime	13.9	15.3	21.1
Compost 2T/Ha	14.4	15.5	18.4
Balance 60kg/ha	15.5	16.5	25.6
Precision wetter 2.5L/Ha	15.6	14.5	18.5
Control	16.2	16.8	21.2
Lure 15L/Ha	16.3	16.9	25.5
Bentonite 1%	19.6	17.0	24.8
Bentonite 3%	20.8	19.5	21.1
Lure & Precision wetter	20.9	18.8	26.8
LSD	4.6	5.4	5.5

The wetting agents and the Bentonite clay addition had the highest soil moisture and some of the highest plant numbers per meter. The numbers in the Balance treatment were also high which was surprising considering that this treatment did not receive a compound start-up fertiliser at seeding.

The biomass based on the Normalised Digital Vegetation Index (NDVI) was captured with a GreenSeeker©, combined with GPS information. These surveys were done three times, 14 June, 17 July, and the 29th of August. The results are presented as separate maps in Figure 4.6.

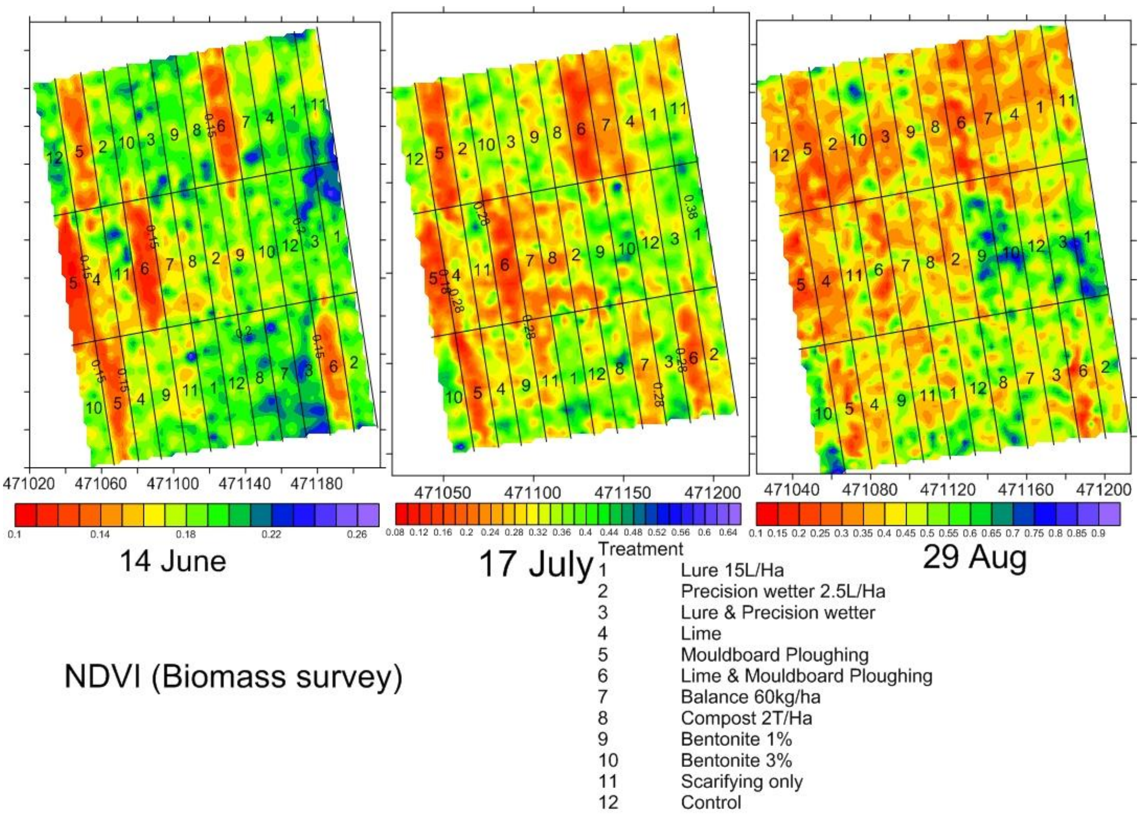


Figure 4.6. Distribution of the biomass at three different dates at the Cordering site.

The mean NDVI values from all the plots are presented in Table 4.3. In addition the grey value (GV) of a biomass image (Figure 4.7) taken in late September is also presented.

Table 4.3. Mean NDVI values for each treatment at three different dates at the Cordering trial site. GV: Grey value from aerial photograph, low is high biomass, high is low biomass.

	Treatment	14-Jun	17-Jul	29-Aug	30-Sep
1	Lure 15L/Ha	0.20	0.36	0.48	29
2	Precision wetter 2.5L/Ha	0.18	0.32	0.42	46
3	Lure & Precision wetter	0.20	0.36	0.46	31
4	Lime	0.17	0.31	0.38	80
5	Mould board Ploughing	0.14	0.21	0.33	100
6	Lime & Mould board Ploughing	0.14	0.20	0.35	81
7	Balance 60kg/ha	0.18	0.26	0.44	59
8	Compost 2T/Ha	0.19	0.32	0.42	31
9	Bentonite 1%	0.18	0.34	0.50	27
10	Bentonite 3%	0.18	0.34	0.51	37
11	Scarifying only	0.18	0.31	0.43	61
12	Control	0.19	0.34	0.46	38
	LSD	0.005	0.030	0.028	GV

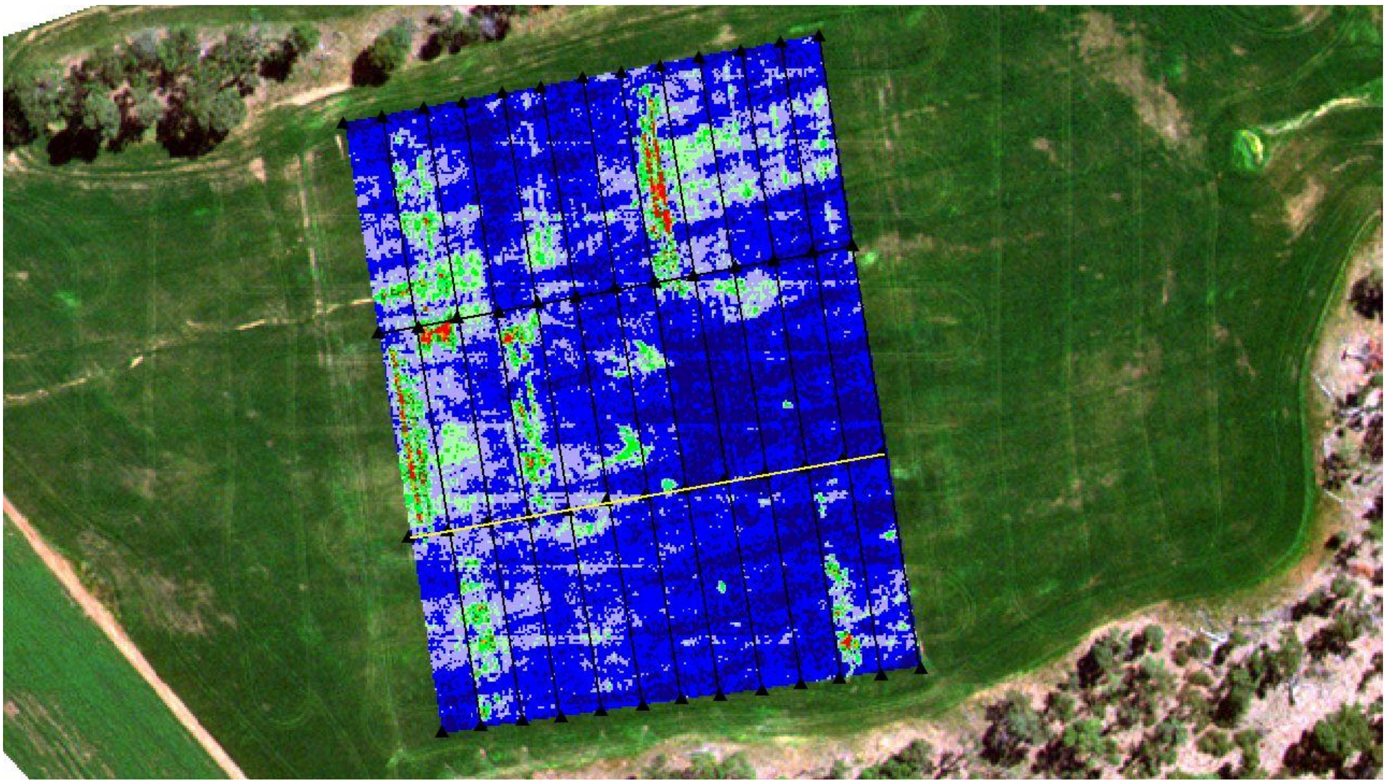


Figure 4.7 Aerial photograph of the trial area enhanced for the biomass.

Similarly to the soil moisture and the plant number, the wetting agent and the Bentonite plots had the highest NDVI readings, and the lowest GV, which indicates the highest biomass. The mould boarded plots were the worst at had initially very little biomass (red plots in Figure 4.6)

The Bentonite had some interesting and unexpected effects on the soil chemical properties, see Table 4.4 while the ploughing had a marked effect on the soil nutrients at the soil surface.

Table 4.4. Effect of Bentonite, and MBP on pH, MED and CEC, 17 July 2012

Treatment	MED	P ppm	K ppm	S ppm	OC (%)	pH CaCl2	CEC
Control	1.9	103	105	40	3.9	5.2	10
Bentonite 1%	1.8	92	97	45	3.6	6.5	16
Bentonite 3%	0.8	112	143	51	3.9	6.8	24
Mould board plough	0.1	42	49	16	1.3	5.2	4

The MED in the ploughed plots reduced greatly as did the 3% Bentonite. Following the ploughing many of the nutrients in the top 10 cm reduced, because they were placed deeper in the profile. The Bentonite had a large and rapid impact on the pH. Within 3 months the pH had changed 1.3 and 1.6 units in the 1% and 3% Bentonite treatments.

The Bentonite was analysed by Dr. Ulrike Troitzsch, Research School of Earth Sciences, Australian National University in Canberra who found the following analysis of the Bentonite, see Table 4.5. For comparison a sample of Wyoming Bentonite and of the top soil were also provided.

Table 4.5. Mineral analysis of the Watheroo Bentonite applied at the site, a sample of Wyoming Bentonite and a sample of the top soil at the site in Cordering.

Sample	Bentonite Watheroo		Bentonite Wyoming		Top soil	
goodness of fit (chi^2)	2.86		5.07		4.53	
	wt.%	*sd*	*wt.%*	*sd*	*wt.%*	*sd*
Quartz	6.0	0.2	8.1	0.3	75.7	0.9
Calcite	24.7	0.2	0.6	0.3		
Ankerite	29.2	0.3				
Gypsum	3.5	0.2	2.1	0.3	1.1	0.3
plagioclase			13.1	0.6		
K-feldspar					2.4	0.5
Hematite					3.5	0.3
Gibbsite					2.6	0.6
Smectite	36.0	0.2	69.1	1.2	0.1	0.1
Kaolinite			2.2	0.5	14.2	0.6
Vermiculite					0.4	0.2
Mica			4.8	0.8		
Halite	0.6	0.1				

The Bentonite that was applied consisted of a lot of Calcite and Ankerite, both Ca/MgCO3 minerals which explains the high neutralising value of the Bentonite (71%). From the analysis provided by the supplier, it was expected that the Smectite content of the Bentonite was about 72%, which would have been twice as much as was actually applied.

One area of contention is the very large increase in the CEC of the soil treated with Bentonite, see Table 4.4. Given the amount of Bentonite that went on and the Bentonite properties the magnitude of those increases are not possible. Investigations in that area are still in progress.

Soil moisture and water repellency samples taken later in the season, reinforced the findings in the crop, see Table 4.6.

Table 4.6. Soil moisture and MED later in the season 03 August 2012

	Treatment	MC (%)	MED
1	Lure	20	2.3
2	Precision	19	2.5
3	Lure&PW	24	1.8
4	Lime	17	3.0
5	Mould board	10	0.0
6	MBP +Lime	12	0.0
7	Balance	17	2.9
8	Compost	18	3.2
9	Bentonite 1%	19	2.2
10	Bentonite 3%	20	1.6
11	Scarifying only	14	2.6
12	Control	20	2.4

An increase in soil moisture compared to the Control only occurred with the combination of Lure and Precision Wetter, but the non-wetting properties had changed, with the mould board ploughed plots being the lowest, followed by the Bentonite and the wetting agents. The low moisture readings in the ploughed plots is largely due to the very different soil texture, dominated by gravel.

Soil samples to measure the biological activity were taken towards the end of the season, and are presented in Table 4.7.

Table 4.7. Total Carbon (TC), and Total Microbial Biomass (TMB) in the top soil of the trial site at Cordering and an indication whether the treatments are significantly different (Sig.)

	Total Carbon (%)			Total Microbial Biomass (µgr/gr)		
F pr.	0.32			0.02		
l.s.d.	3.034	Mean	Sig.	7.49	Mean	Sig
1	MBP	1.74	a	MBP	1.5	a
2	Lime & MBP	3.35	ab	Lure & PW 15L & 2.5L/ha	5.6	ab
3	Lime	4.01	ab	Lime & MBP	5.9	ab
4	Balance 60kg/ha	4.47	ab	Control	7.7	abc
5	Bentonite 3%	4.83	b	Compost 2T/Ha	8.4	abcd
6	Control	4.9	b	Lure 15L/Ha	8.5	abcd
7	Lure & PW 15L & 2.5L/ha	4.96	b	Balance 60kg/ha	9.5	bcde
8	PW 2.5L/Ha	5.09	b	PW 2.5L/Ha	9.5	bcde
9	Lure 15L/Ha	5.09	b	Lime	11.6	bcde
10	Compost 2T/Ha	5.34	b	Scarifying	13.8	cde
11	Scarifying	5.34	b	Bentonite 3%	15.7	de
12	Bentonite 1%	6.21	b	Bentonite 1%	16.6	e

While most of the treatments were not statistically significantly different (ie. contain the same letter), the two extreme treatments, MBP and Bentonite were different. In the MBP plots a lot of the organic matter is placed at depth, while the introduction of heavy rates of clay and carbonate products had a positive influence on the microbial activity. It is well known that clays in particular have a positive effect on the biological activity because it provides good shelter and refuge for the microbes. The improved pH in the Bentonite plots might also have had a positive influence on the biology of the soil.

Yield Results

Probably due to a trend in some of the soil properties in the middle rep (see Figure 4.3 for non-wetting, and Figure 4.5 for PBI and gravel), also a clear trend in the yield data of that rep was found, see Figure. 4.8.

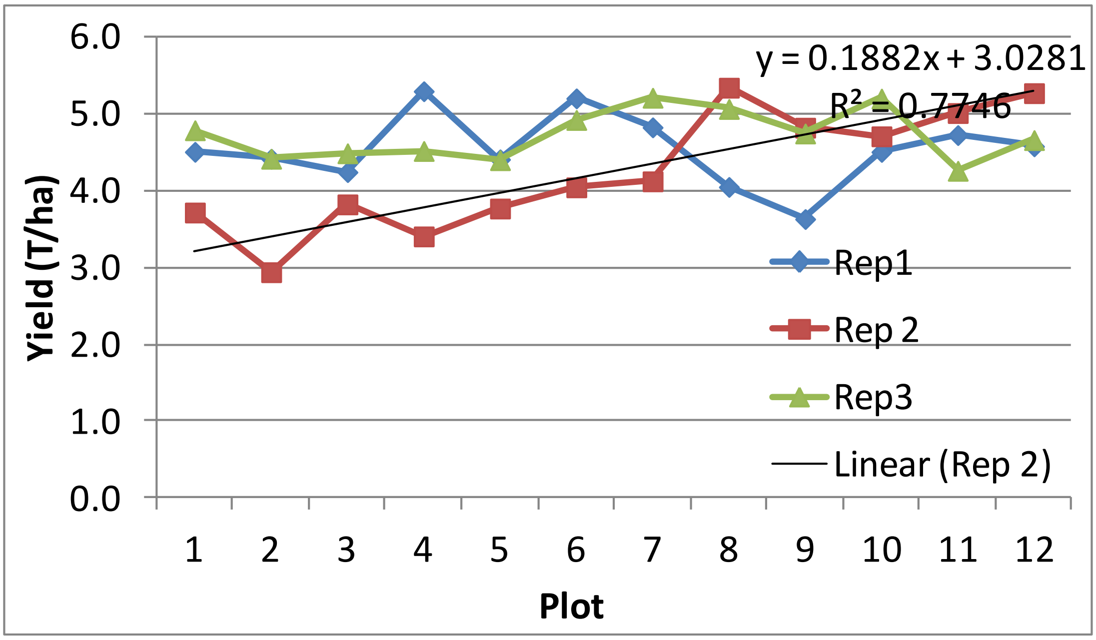


Figure 4.8. Yield (T/ha) of each plot in relation to the order in the replicate at the Cordering trial.

In the statistical analysis of the yield data, this trend in Rep 2 was included in the analysis as a covariance, which had some effect on the calculation of the mean of the treatments. Table 4.8 shows all the measured yield and grain quality parameters adjusted for the covariance, and the measure of significance (Fpr.). Max results are underlined.

Table 4.8. Yield quantity and quality and some statistical parameters at the Cordering trial site.

Parameter	Yield (T/ha)	Protein %	Screenings	Colour
F pr.	0.074	0.004	0.018	0.041
Balance 60kg/ha	4.12	11.2	5.4	55.7
Bentonite 1%	4.96	10.8	5.7	56.3
Bentonite 3%	4.86	11.4	7.5	55.3
Compost 2T/Ha	4.67	10.7	4.3	55.0
Control	4.66	10.9	5.3	56.0
Lime	4.18	10.8	4.5	55.1
Lime & MBP	4.02	11.9	3.9	55.7
Lure & PW 15L & 2.5L/ha	4.68	10.8	4.3	54.9
Lure 15L/Ha	4.73	10.5	5.5	55.3
MBP	4.43	11.1	2.9	55.7
PW 2.5L/Ha	4.32	10.7	3.9	55.3
Scarifying	4.42	11.5	4.6	55.7
l.s.d.	0.58	0.6	1.9	0.8

The ranking of the treatments and significance (same letter in the group means not significant) and the cost benefit from the treatments are presented in Table 4.9.

Table 4.9. Yield ranked and level of significance and the cost(-)/benefit(+) of the treatments compared to the Control at the Cordering trial site.

Parameter	Yield(T/ha) Mean	Sig.	Extra benefit ($) from treatment compared to Control (@$300/tonne)	Extra cost to apply treatment ($/ha)	Cost/Benefit from the Treatments ($/ha)
Lime & MBP	4.02	a	-191	$240	-$431
Balance 60kg/ha	4.12	ab	-162	$66	-$228
Lime	4.18	abc	-143	$120	-$263
PW 2.5L/Ha	4.32	abcd	-100	$22	-$122
Scarifying	4.43	abcde	-69.6	$40	-$110
MBP	4.43	abcde	-68.1	$120	-$188
Control	4.66	bcde	0	0	0
Compost 2T/Ha	4.67	bcde	3.9	$334	-$330
Lure & PW 15L & 2.5L/ha	4.68	bcde	6	$97	-$91
Lure 15L/Ha	4.73	cde	22.5	$75	-$53
Bentonite 3%	4.86	de	61.2	$3000	-$2940
Bentonite 1%	4.96	e	90	$1000	-$910

Given the good season, few of the treatments resulted in significantly different yields. From Table 4.9 it is clear that only the extreme yields of Lime & MBP, the Balance and the Lime were significantly different from the highest yields in the Bentonite plots. The rest was statistically not different. No treatment was economically better than the Control. The highest yielding treatments were also the most expensive to apply. In statistical terms none of the highest yielding treatments was better than the Control.

Runoff

The runoff was measured with little flumes positioned in such way that runoff water was trapped in a little furrow and channelled through a flume, which is a contraption that funnels the water through a narrow opening. The height of the water flowing through the opening was measured at 15 minute intervals, and using a calibration curve for such an opening the height of water was converted to a flow in l/sec. In Figure 4.9 an example of a flume in the field is presented, after a lot of rain sand and gravel was deposited in the flume.

Figure 4.9. Flume in the field at the trial site in Cordering. Pipe to the left contains the water level recorder.

The runoff tends to be very variable and prone to errors in measurements caused by blocked flumes and not being able to capture all the runoff from a plot due to wheel tracks running across the plots and crossing plot boundaries. The slope of the plots used to measure the runoff was predominantly north-south but there was some cross fall as well which enabled runoff to 'escape' from the plots because they were not entirely hydraulically isolated. A sample of the runoff in early June, is presented in Figure 4.10.

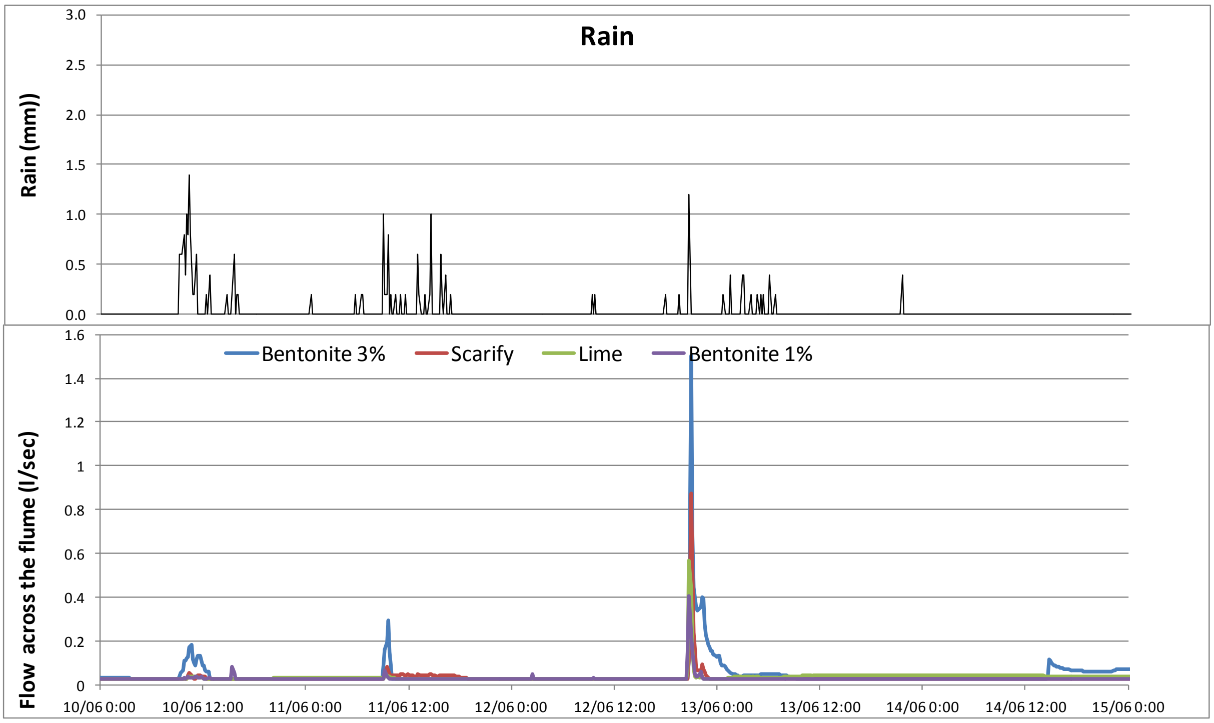


Figure 4.10. Runoff from four plots as indicated in the legend (bottom) and the rain (top) during some rainfall events in early June at Cordering.

It was interesting that during the rainfall event around the 10th of June not much runoff was generated while the total amount was significant (8mm) higher than the rainfall on the 12th of June when 1.5mm of rain fell in 10 minutes, which generated much more runoff. The larger amount of rain fell over several hours and could infiltrate more easily. On the second occasion the soil surface which was still bare generated more runoff, with the Bentonite 3% the most. The Bentonite might have had some sealing effect which prevented the water from infiltrating rapidly. It is however difficult to come to any conclusions based on so little data.

5. Discussion of Results

While some of the non-wetting treatments were clearly beneficial and impacting on the non-wetting soil properties, germination counts and final yield, it was very difficult to improve on the yield of the Control of 4.66 T/ha. According to the landholder it is difficult to establish crop on these soils, due to the non-wetting but once it is established, the gravelly loamy duplex soils are able to produce respectable yields provided the rainfall is there.

With 405 mm for the growing season, which came at regular intervals and at the right time compared to the time of sowing non-wetting did not become a major issue at this trial site in 2012. The following figure (Figure 5.1) illustrates that non-wetting can be a significant issue at that site. In the figure an oat crop was sown from right to left in 2010 (a very dry year), across a lupin crop grown in 2009 and sown top to bottom. Whenever the row of oats 'hit' the previous year lupin row, the germination was improved. Elsewhere non-wetting delayed the germination by weeks.

Figure 5.1. Rows of oats (sown left to right) established on old lupin rows, sown top to bottom in 2010.

Many of the treatments have a residual value that in some cases will last for many years, such as the mould board plough, Bentonite and lime treatments. It will be of interest to see what the lasting impact is of the Bentonite on the pH, the wettability, weed germination, and ultimately the yield. The Lure treatment is said to have another year effect.

The crop development in mould board ploughed treatments was surprising, because the results of those treatments have been very successful elsewhere in the State. The crop establishment was extremely poor. It is thought that this might have been a function of the inter-locking gravel in the ploughed plots at the surface, see Figure 5.2. Compare that to the organic rich loamy top soil, which is normally non-wetting, in the Control, see the same figure.

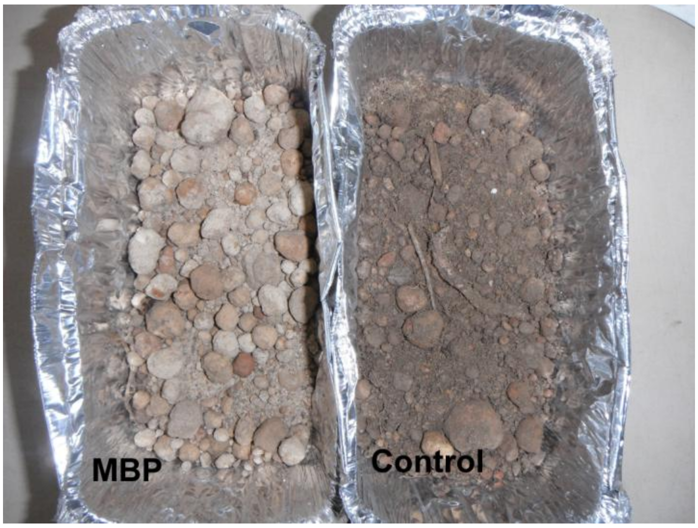


Figure 5.2. Gravel and sand in the ploughed plots (MBP) and the rich organic topsoil in the Control (Control) at the Cordering trial site.

The sub-crown internodes of the plants that germinated in the ploughed plots were ‘gnarly’ and twisted (see Figure 5.3) whereas the plants germinating in the Control were straight.

Figure 5.3 Plates of seedling from the ploughed plots (left) and from the Control plots (right) at the Cordering trial site.

It is possible that the rainfall (40mm) that fell after ploughing created a firm surface with gravel stones of different sizes with washed out sand between them. Seeding would have disturbed this surface but not changed it. The press wheel on the seeder bar would then have slightly compacted the gravel again following the placement of the seed.

If this is the only reason, then mould board ploughing of these soil types needs to be done with caution because of the type of gravel that can be brought up to the surface. Reducing the plough depth might make a difference.

In Figure 5.4 a soil profile of the mould board ploughed plot is presented. The non-wetting organic rich top soil is placed at depth and covered over by a layer of wettable subsoil.

Figure 5.4 Soil profile of the mould board ploughed plot at the Cordering trial site.

The subsoil consisted of fine and coarse sandy gravel which might have inhibited seed germination.

It was interesting to see how the mould board ploughed plots recovered. Towards the end of season, when most of the other plots were haying-off, the ploughed plots remained green for longer, see Figure 5.5.

Figure 5.5. Haying-off of the crop growing on a Bentonite plot (left) next to a mould board ploughed plot (right) which remained greener at the Cordering trial site.

The ploughed plots yielded only 0.2 t/ha less than the Control, which considering the lack of germination 3 weeks after seeding was surprising. This effect of ploughing on plant growth has been found elsewhere. Given the large amount of soil disturbance, the availability of nutrients later in the season (placed deeper) and improved water penetration allowed for a later maturing crop. In addition the low plant numbers on the ploughed plots, resulted in more moisture available for crop growth for the individual plants which were able to hold on longer, and remain green for longer.

6. Recommendations

Certain treatments: clay (Bentonite), wetting agents and ploughing showed some promise, even though it was difficult to improve the yield from the Control.

This year (2013) the plots will be sown early to canola, at a time that non-wetting might have more of an impact.

In addition a new trial site has been established where mould board ploughing, 1% Bentonite, and LureH2O are going to be implemented again.

The ploughing will be done at a shallower depth while only 1% of Bentonite will be added. The Lure H2O will be applied preseeding in the beginning of April, but also shortly after seeding.

7. Appendices

The Cordering trial featured highly with a number of groups visiting during the year and was the main focus of 2 field days organised by the West Arthur trials group. A summary is provided in Table 7.1.

Table 7.1. Extension and communication activities featuring the Cordering trial site.

Date	Group	Attendance	Comments
17 July 2012	West Arthur Trial's Group	52	Mainly growers and agribusiness
24 August 2012	Dr. P. Blackwell	1	Scientific orientation regarding non-wetting
10 September 2012	GRDC, part of the western panel	7	GRDC Western Panel and Agribusiness
19 October 2012	West Arthur Trial's Group	65	Mainly growers and agribusiness
25 October 2012	Grain Soil Management (DAFWA)	10	Scientific orientation regarding non-wetting soils
15 March 2013	DAFWA Crop Update	45	Growers, agribusiness and agri-researchers.

Project Title:	Amelioration strategies for non-wetting gravel soils in a high rainfall area
GRDC Project No.:	KW11/12-1of1
Researcher:	Michelle Gooding,
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Objectives	To trial a range of treatments on non-wetting forest gravel soils in the south west, in a high rainfall area, to determine which, if any, will increase water penetration and what soil characteristics have altered as a result of the treatment. By increasing water infiltration it is expected that soil cover (plants) will increase and consequently reduced water and wind erosion. Less staggered germination will increase yield and reduce weed burden which are not only economic drivers but ultimately provide soil cover, build soil carbon and protect against erosion.
Background	Non-wetting is a major problem of the gravelly soils in the high rainfall area of the South Western wheat belt of WA. Non-wetting is caused by a build up of waxes around the soil particles as a product of the breakdown of organic matter. It results in delayed emergence of the crop, staggered germination of weeds, affects the availability of phosphorus as a major but less mobile nutrient and ultimately affects yield.
Research	A large scale trial was implemented near Cordering in the West Arthur Shire in 2012, to investigate the effectiveness of a number of management options to alleviate the non-wetting properties or to reduce its impact. They included: the use of wetting agents (Lure and Precision Wetter, as a blanket spray and banded), organic fertilisers (compost and humus pellets), mould board ploughing (with and without lime), claying (2 rates: 9 and 28 t/ha @ $110/tonne), scarifying and liming at the surface, as well as a Control which consisted of the 'standard' practice. The clay consisted of Watheroo Bentonite, because other clay sources

	were not available at the time. Most of the options were implemented prior to seeding.
Outcomes	Most treatments that altered the wetting properties of the soil improved the grain yield also. The mould board ploughing treatment was an exception due to the introduction and inter-locking gravel in the topsoil which might have impeded the germination. Once established the crop on the ploughed plots did very well. None of the treaments were able to economically improve the yield because the Control plots yielded exceptionally well.
Implications	Certain treaments while not economically outyielding the Control, did show some promise, and worthy of a repeat trial, under circumstances that might be more amenable to expressing the non-wetting properties of the soil.
Publications	Darkan CropUpdate 2013 paper. *Non-wetting soils in high rainfall forest gravel soils.*